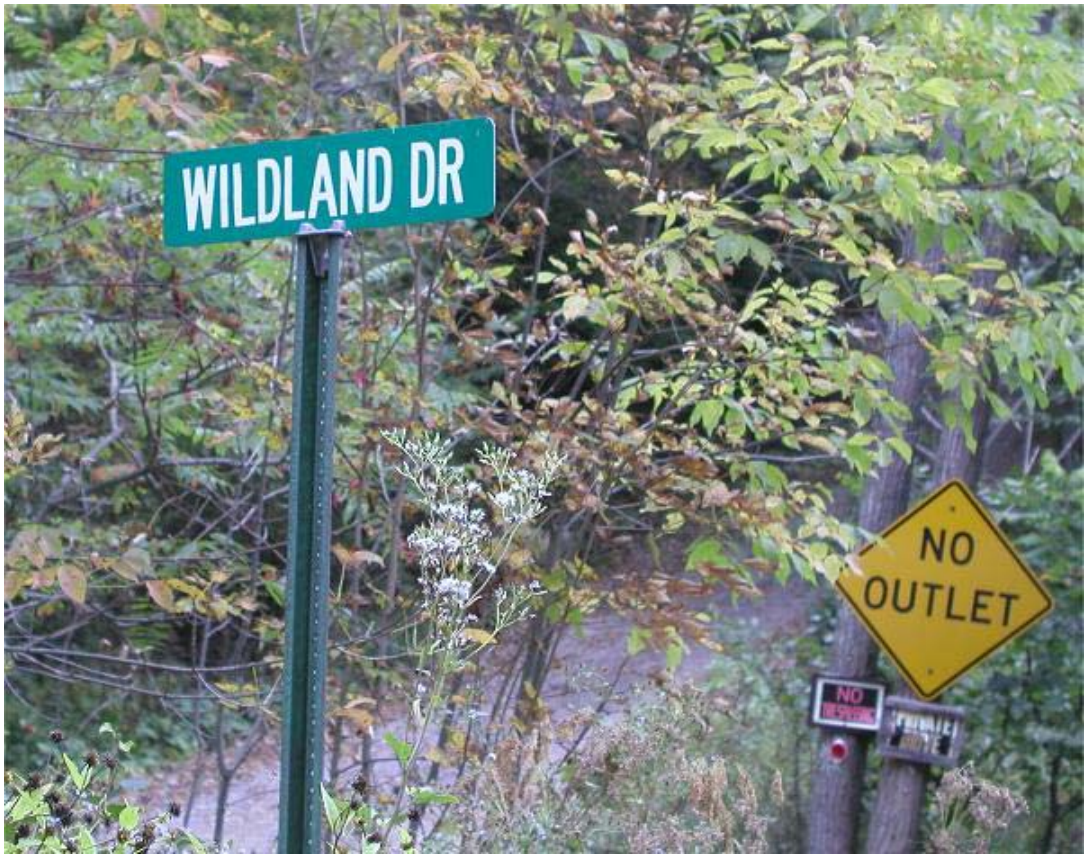
Forest and Green Infrastructure Loss in Maryland 1997-2000, and Implications for the Future



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ABSTRACT

We used Geographic Information Systems (GIS) techniques and field assessment to examine land conversion between 1997 and 2000. Our objectives were to determine patterns of forest loss, impacts to natural landscape connectivity (specifically, to Maryland's green infrastructure hub-corridor network), and to predict future trends. We found that Garrett county lost the most forest (over 7000 ac) of any county in Maryland between 1997 and 2000, and by far the most green infrastructure forest. By region, Western Maryland lost more green infrastructure (over 8600 ac) than the rest of the state combined. Most of its forest loss was in formerly large, contiguous blocks; whereas much (71%) of the forest lost elsewhere in the state was in small or isolated woodlots, and outside the green infrastructure. This reflects the fragmented state of most of Maryland's forests. Western Maryland (especially Garrett County), on the other hand, contains more contiguous, more ecologically and economically valuable forest, but is now undergoing the same sort of exurban development and habitat fragmentation common in the central and southern counties. The Eastern Shore, where many recent (post-2000) land protection efforts have focused, suffered by far the fewest losses of forest and green infrastructure during the study period. Most of the forest lost between 1997 and 2000 was converted to low-density residences. In most cases, >50% of tree cover was retained on site after development, but the forest was fragmented. In addition to absolute forest loss, green infrastructure functional loss was significant. 7 hubs and 32 corridor segments, totaling over 13,000 ac, lost over 10% of their area. The hub-corridor network was interrupted in 28 areas. Fortunately, for 24 of the 28 broken routes, alternate pathways compensated for these obstacles, demonstrating the value of redundancy in conservation networks. However, if current trends continue, a large fraction of Maryland's green infrastructure may be seriously degraded by 2020. Finally, a development risk model performed better than random chance at predicting forest loss and, by using suitable thresholds, can help focus protection efforts. An improved development risk model is under development.

BACKGROUND

Maryland's Green Infrastructure Assessment is a tool developed to help identify and prioritize areas in Maryland for conservation and restoration. The goal is to target those areas of greatest statewide ecological importance, as well as those at greatest risk of loss to development. The green infrastructure (GI) network identifies large contiguous blocks of natural resource lands (hubs), interconnected by natural corridors to allow animal and plant propagule dispersal and migration, in the hope of maintaining viable and persistent metapopulations. Hubs and corridors were ranked within their physiographic region for a variety of ecological and development risk parameters, as well as combinations of these. Prioritization was also done on a finer scale (approximately a third of an acre) for ecological importance and vulnerability to development, allowing a more detailed analysis for site prioritization within the network. Model output was reviewed by field ecologists and county planners, and compared to other habitat delineations and reserve systems. In May 2001, Governor Glendening signed into law the GreenPrint program, which earmarked funds specifically to protect land in the green infrastructure network, where willing fee simple or conservation easement sellers were found.

Recently, the Maryland Department of Planning released coverages of year 2000 land use. This was a Level 2 U.S.G.S. classification of land use/land cover for each Maryland County and Baltimore City (Maryland Department of Planning, 2001). It was initially developed using high altitude aerial photography and satellite imagery (Maryland Department of Planning, 2001). Urban land use categories were further refined using parcel data from MDPropertyView (Maryland Department of Planning, 2001). We compared land use in 2000, land use in 1997, and the green infrastructure network, to examine spatial patterns of land conversion. Specifically, we were interested in the loss of green infrastructure to development, where this was occurring, and to what degree. We also used these data to evaluate the predictive power of a development risk

model created for the Green Infrastructure Assessment, as well as a growth simulation model created by MDP. Finally, we assessed the functional impact of new development on the green infrastructure, using both GIS and field data.

METHODS

GIS Evaluation of Forest and Green Infrastructure Loss

We selected areas developed in 2000 from MDP land use coverages. The metadata (Maryland Department of Planning, 2001) stated that various land use categories were identified using 1997 SPOT satellite imagery and 2000 aerial photography. Land uses were then digitized in a vector format (Maryland Department of Planning, 2001). Urban land use types were identified/verified using parcel information available from the 2000 Edition of MDPropertyView (Maryland Department of Planning, 2001). The selected areas included:

> 11 Low-density residential - Detached single-family/duplex dwelling units, yards and associated areas. Areas of more than 90 percent single-family/duplex dwelling units, with lot sizes of less than five acres but at least one-half acre (.2 dwelling units/acre to 2 dwelling units/acre).
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> 12 Medium-density residential - Detached single-family/duplex, attached single-unit row housing, yards, and associated areas. Areas of more than 90 percent single-family/duplex units and attached single-unit row housing, with lot sizes of less than one-half acre but at least one-eighth acre (2 dwelling units/acre to 8 dwelling units/acre).
>
> 13 High-density residential - Attached single-unit row housing, garden apartments, high-rise apartments/condominiums, mobile home and trailer parks. Areas of more than 90 percent high-density residential units, with more than 8 dwelling units per acre.
>
> 14 Commercial - Retail and wholesale services. Areas used primarily for the sale of products and services, including associated yards and parking areas.
>
> 15 Industrial - Manufacturing and industrial parks, including associated warehouses, storage yards, research laboratories, and parking areas.

We excluded:

> 16 Institutional - Elementary and secondary schools, middle schools, junior and senior high schools, public and private colleges and universities, military installations (built-up areas only, including buildings and storage, training, and similar areas), churches, medical and health facilities, correctional facilities, and government offices and facilities that are clearly separable from the surrounding land cover.
>
> 17 Extractive - Surface mining operations, including sand and gravel pits, quarries, coal surface mines, and deep coal mines. Status of activity (active vs. abandoned) is not distinguished.
>
> 18 Open urban land - Urban areas whose use does not require structures, or urban areas where non-conforming uses characterized by open land have become isolated. Included are golf courses, parks, recreation areas (except areas associated with schools or other institutions), cemeteries, and entrapped agricultural and undeveloped land within urban areas.

Codes 17 and 18 fell under “Urban Built-Up”, but were too broad to tell whether they were still forested or not. Unlike MDP’s 1997 data, the 2000 data did not appear to differentiate between non-developed and developed status within areas classified as “Institutional” (Code 16). For example, the entire National Agricultural Research Center was shown as “Institutional”, whereas in 1997, part was shown as forested. This was true for other areas we examined also. Thus, we removed “Institutional” areas from further consideration.

We then selected areas identified as forest in 2000 from MDP land use coverages, and areas identified as forest in 1997 from MDP land use coverages. After correcting for positional errors (the 1997 and 2000 land use coverages did not overlay exactly, and had to be shifted slightly), we selected areas developed in 2000 that were identified as forest in 1997 (where developed polygons intersected areas identified as forest). There were also areas where data did not overlay well, despite attempts to correct this. We therefore filtered out areas that were less than 5 acres, because they were likely spatial errors. Results were tabulated by county. Forest loss may have been an underestimate, since we discounted institutional, extractive, and open urban land, and areas <5 ac.

We next identified green infrastructure converted from forest to development between 1997 and 2000. Results were tabulated by county. Again, losses may have been underestimated. We also calculated the mean cell ecological score (described in *Maryland's Green Infrastructure Assessment: Detailed Methods, version 5.1*) by county to get an idea of the quality of GI lost. Finally, we calculated the percentage of each hub and corridor lost, to identify which areas were most significantly impacted.

Field verification

We selected 100 areas of green infrastructure forest lost between 1997 and 2000 that were at least 30 acres in size. Of these, seventy-one were visited, based partly on logistical constraints.

Field verification of MDP data was conducted by car and occasionally by foot for fine scale information. Standardized data sheets (see Appendix A) were used to record the amount and the dominant type of land use (if any), the amount of forest cover remaining, and the dominant tree size class in the canopy. Photographs were also taken of most of the developed areas.

The land use types ranged between low, medium and high-density residential development and more intense, non-residential development. If a site had not been developed or was predominantly undeveloped at the time of the field survey, the dominant habitat type at the site was recorded (for example, evergreen forests were distinguished from mixed or deciduous forest). In some cases, both residential development and forest were marked for the predominant land use. This was the case where continuous forest remained separate from developed areas. The percentage of forest cover was estimated and categorized by 25% increments (0-25%, 25-50%, etc.). Dominant tree size class was estimated based on the average tree diameter at breast height (dbh). It is important to note that land use was recorded based on the dominant land use type. Therefore, areas that had one or more buildings, but were predominantly forested, were recorded as ‘forest’.

These data were combined with the MDP data set to analyze and assess the impact of recent development on Maryland's green infrastructure.

Functional impact by county

The field data were combined with the GIS data to analyze and assess the impact of development between 1997 and 2000 on Maryland's green infrastructure. The functional impact of development on corridors or hubs was estimated by the number of corridor or hub breaks that resulted from development, the type of development that occurred, the percent of area that was converted to development, the number of breaks and road crossings that were present before development, percent of forest cover retained within developed areas, and ecological ranking before development. The ecological value of impacted hubs and corridors was assessed using various criteria, including the composite ecological percentile rank of each hub within its physiographic region and, for each corridor, the top ecological ranking of hubs it connected, and whether it linked hubs in the top ecological tier. Hub ecological rankings (eco-percent: 0 indicates best, 100 worst), described in Weber (2001), were computed from biological data, measures of available habitat, hub intactness, remoteness, and the condition of the neighboring landscape. Corridor ecological rankings placed a greater emphasis on what they linked, and how effective that linkage was (top tier: 1 indicates in the top tier, 0 not). For example, corridors that connected high-ranking hubs were considered more important than those that connected low-ranking hubs. Also, corridors with breaks, road crossings (especially if they were major roads), or insufficient width were considered more difficult for wildlife and seeds to traverse.

The most critical task of the functional assessment was to identify where the hub/corridor network was broken by development. Breaks in the network refer to places where recent development splits or nearly splits a pathway, thereby restricting wildlife and seed dispersal through the green infrastructure in that region. Breaks were assessed visually by examining digital maps. Only breaks between large areas (>100 ac) in the GI were considered; small areas isolated from the network were excluded from the tally. Developments that severed linkages prior to 1997 also were not included in the analysis. Where landscape linkages were broken by development, we looked for viable alternate routes. Hubs and corridors were numbered according to their unique ID numbers, which can be referenced on GIS maps.

Evaluation of development risk model

We compared green infrastructure forest lost between 1997 and 2000, with a development risk model (described in Weber, 2001), to assess the model's predictive power. This model divided all developable land in the state into 0.3 ac grid cells, considered the distributions and strengths of various protective mechanisms and development incentives, and estimated conversion probabilities for each cell relative to the rest of the state. This was also done at a larger scale, comparing the conversion risk of each hub and corridor segment. Both hub/corridor scores and cell scores were evaluated within newly developed areas. We examined mean risk values and distribution curves to see if thresholds existed that would be useful predictors of future development, if 1997-2000 trends continued into the future. For example, were more areas with

mean risk values >50 (i.e., in the top 50%) developed than areas with mean risk values <50 (i.e., in the bottom 50%), and if so, by what margin?

RESULTS

Forest and Green Infrastructure Loss

Tables 1 through 4 list the acres and percentages of land converted from all forest to development, and from green infrastructure forest to development, by both county and region. Table 5 lists, for green infrastructure forests, the ecological importance of the land converted.

Table 1
Loss of all forest between 1997 and 2000, by county (MDP data).
(in descending order by acres lost)

COUNTY	Acres of land converted from forest to development 1997-2000	Acres of forest land in 1997	% of forest converted to development 1997-2000
Garrett	7,139	280,034	2.5%
Anne Arundel	3,947	109,048	3.6%
Prince George's	3,415	128,072	2.7%
Montgomery	3,209	92,096	3.5%
Washington	3,083	103,572	3.0%
Frederick	2,799	124,578	2.2%
Baltimore	2,133	127,886	1.7%
Carroll	1,926	64,934	3.0%
Charles	1,745	172,388	1.0%
St Mary's	1,711	122,687	1.4%
Cecil	1,012	82,989	1.2%
Harford	902	94,149	1.0%
Calvert	674	68,574	1.0%
Howard	447	47,964	0.9%
Queen Anne's	443	62,877	0.7%
Allegany	406	197,186	0.2%
Wicomico	349	92,432	0.4%
Baltimore City	304	3,732	8.1%
Worcester	275	155,010	0.2%
Talbot	259	40,855	0.6%
Caroline	162	62,977	0.3%
Dorchester	159	113,621	0.1%
Kent	156	46,682	0.3%
Somerset	74	70,242	0.1%
TOTAL	**36,729**	**2,464,585**	**1.5%**

Table 2
Loss of forest between 1997 and 2000, by region (MDP data).

REGION	Acres of land converted from forest to development 1997-2000	Acres of forest land in 1997	% of forest converted to development 1997-2000
Western	13,427	705,370	1.9%
Southern	11,492	600,769	1.9%
Central	9,933	513,750	1.9%
Eastern	1,877	644,696	0.3%

Table 3
Loss of green infrastructure forest between 1997 and 2000, by county (MDP data).
(in descending order by acres lost)

COUNTY	Acres of GI converted from forest to development 1997-2000	Acres of GI forest land in 1997	% of GI forest converted to development 1997-2000
Garrett	6,057	244,153	2.5%
Washington	1,500	73,161	2.1%
St Mary's	1,061	74,829	1.4%
Charles	883	135,895	0.6%
Frederick	849	75,033	1.1%
Montgomery	796	52,785	1.5%
Prince George's	641	74,765	0.9%
Anne Arundel	564	54,148	1.0%
Cecil	559	52,722	1.1%
Baltimore	514	65,162	0.8%
Calvert	388	43,592	0.9%
Harford	235	52,936	0.4%
Allegany	226	173,574	0.1%
Howard	182	22,932	0.8%
Wicomico	170	69,152	0.2%
Worcester	165	124,231	0.1%
Dorchester	140	104,204	0.1%
Carroll	122	16,319	0.7%
Queen Anne's	107	41,051	0.3%
Talbot	96	22,406	0.4%
Caroline	72	41,700	0.2%
Somerset	66	49,960	0.1%
Kent	48	25,648	0.2%
Baltimore City	27	951	2.8%
TOTAL	**15,468**	**1,691,309**	**0.9%**

Table 4
Loss of green infrastructure forest between 1997 and 2000, by region (MDP data).

REGION	Acres of GI converted from forest to development 1997-2000	Acres of GI forest land in 1997	% of GI forest converted to development 1997-2000
Western	8,632	565,921	1.5%
Southern	3,537	383,229	0.9%
Central	2,435	263,807	0.9%
Eastern	864	478,352	0.2%

Table 5
Mean cell ecological score of green infrastructure converted from forest to development between 1997 and 2000, by county (MDP data).
Cell ecological scores range from 100 (best) to 0 (worst).

County	Mean cell score of GI converted from forest to development 1997-2000
Dorchester	84.5
Talbot	83.3
Garrett	83.0
Charles	82.2
Calvert	80.8
Washington	80.4
St Mary's	79.0
Cecil	78.1
Allegany	75.1
Howard	75.0
Somerset	74.8
Worcester	74.3
Baltimore	73.2
Queen Anne's	70.3
Caroline	69.7
Frederick	69.4
Montgomery	69.1
Wicomico	67.9
Carroll	66.6
Prince George's	64.8
Harford	61.0
Baltimore City	57.3
Anne Arundel	56.9
Kent	49.1

In addition to absolute forest loss, green infrastructure functional loss was significant. Two hubs and 8 corridor segments, totaling 4353 ac, lost more than 25% of their area. 5 more hubs and 24 more corridor segments, totaling 9201 ac, lost between 10 and 25% of their area.

Field verification

Seventy-one of the largest developed polygons were surveyed in the summer and fall of 2002. These field surveys were conducted to verify the accuracy of the GIS data. Of the polygons regarded as developed by MDP data, 91.5% were indeed developed. In some cases, areas that were recorded as developed by MDP were in the planning phase, had been partially cleared but not built upon, or were abandoned after utilities were in place. 68.5 % of the 7589 acres surveyed (43 sites) showed low density development (5201 acres) (Table 6). Fewer acres were converted to medium-density development, only 10.5 % (800 acres). The least amount of converted land was devoted to high-density and commercial development, 0.4 % and 3.4 % respectively. 40.2 % of the total sampled areas had at least some intact forest (3054 acres). Furthermore, most of the surveyed areas retained at least half of their forest canopy intact (5250 acres, 68.9 %; see Table 7). Only 11 % of the sites had <25% of their forest remaining. Some photos from the field verification are shown in Figure 1.

Table 6
"Developed" acreage categorized by land use type. Data from areas sampled in Summer/Fall, 2002.

	Acreage	% of sampled acreage	Total Number of Sites	% of sampled areas	Mean Acres	Maximum Acres	Minimum Acres
Sampled areas without buildings	383.9	5.1	6	8.5	64.0	146.5	33.7
Sampled areas with buildings	7205.3	94.9	65	91.5	110.9	878.0	31.2
Sampled areas with low-density development	5200.6	68.5	43	60.6	120.9	878.0	31.2
Sampled areas with medium density development	799.6	10.5	13	18.3	61.5	159.8	36.6
Sampled areas with high density development	99.4	1.3	2	2.8	49.7	66.2	33.2
Sampled areas with commercial development	258.7	3.4	2	2.8	129.3	214.1	44.6
Sampled areas still containing forest	3054.2	40.2	30	42.3	101.8	421.9	33.7

Table 7
Remaining acreage with various percentages of intact forest

	Acreage	% of sampled Acreage	Total Number of Sites	% of Sampled Areas	Mean Acres	Maximum Acres	Minimum Acres
Areas with 0-25% forest	840.3	11.0	14	19.7	60.0	214.1	31.2
Areas with 25-50% forest	939.2	12.4	14	19.7	67.1	139.8	34.6
Areas with 50-75% forest	3411.3	44.9	23	32.4	148.3	878.0	31.3
Areas with 75-100% forest	1839.0	24.0	19	26.8	96.8	254.8	33.7
Areas with unknown % forest	559.4	7.4	1	1.4	559.4	559.4	559.4

Fig. 1. Sample photos from site visits of recent development.

New medium-density housing in central Maryland

New low-density housing in Garrett County

Development on steep slopes near Deep Creek Lake, without sediment control.

Development plans in Garrett County.

Functional impact by county

A detailed assessment of potential impacts to the green infrastructure network follows, organized by county. Each impacted hub or corridor is referenced by its unique ID. Maps that show the location of the affected hubs and corridors are in Appendix B. Summary statistics are provided in Table 8. Where alternate pathways may compensate for impaired pathways, it is indicated. It is important to note that green infrastructure corridors and hubs were defined using 1991-1993 satellite imagery displaying land coverage. Development prior to 1997, and development between 1997 and 2000 was identified using MD Department of Planning 1997 and 2000 land use data, respectively. Therefore, the green infrastructure contains areas that wooded as of 1993, but were identified as 'developed' by the Department of Planning in 1997. These areas are described as 'developed prior to 1997' below.

Allegany County

There were a small number of sites developed within the central region of Allegany County between 1997 and 2000. None appear to threaten the hub and corridor network other than those found in corridor 61. This 367 acre corridor lost 3.3% of its area and was completely broken by this development, however previous land use in the area had already severed this pathway. Prior to development this corridor had no breaks, one secondary road, one county road and four railroad lines. It is connected to one of the highest-ranking hubs in its physiographic region. Other pathways may be functional as alternate routes.

One hub/corridor pathway was split by a developed site in this county. Since this pathways was broken before 1997, this break has not been included in Table 8.

Anne Arundel County

All the corridors in Anne Arundel County are in the state's lowest ecological rank (lowest quintile) because the area is so heavily developed. Much of the forest has been cleared for development. Restoration work would be necessary to establish any viable corridors. The ecological functions of this region's hub and corridor network cannot be assessed without in-depth field surveys, however, based on our study many of these areas appear to be non-functional.

Hub 293 and corridor 737 both lost large areas to two developments, 42% and 3.6% of their areas, respectively. The connection linking them was broken at two sites. These sites are now commercial developments with less than 25% of their forest retained. Two small regions within the hub/corridor were completely isolated. Alternate routes are inaccessible. The hub, which also serves as a connection between the Patuxent River and Patapsco Valley, was essentially destroyed. Other potential connections had a relatively low ecological ranking prior to development. The ecological ranking of corridor 745 is in the bottom quintile of the state. It has five breaks and crossed two roads. Corridor 753 is also one of the lowest ranking corridors in this physiographic region; it has three breaks and crosses seven roads. It retains 40% of its natural cover. Another low-ranking corridor, 871, is an alternate route in this region. Its ecological rank is in the lowest quintile in the region: this corridor has three breaks, crosses nine roads and retains only 44% of its natural cover.

Corridor 789 may potentially be split by a development covering 146.5 acres, since a permit was granted for its development. As of autumn, 2002 this corridor had not been developed. It had five breaks, and crossed 10 roads prior to development.

Summing up in this county there were two links broken by developed sites. For both, alternate pathways do not exist due to previous land use in the region.

Baltimore County

The majority of developed areas in Baltimore County over the time period examined are relatively small.

In the Dickey Hill Forest-Gwynns Falls Park area, hub 237 lost 19 of its 965 acres. Some of this hub was left isolated. Nine sites were developed in this hub between 1997 and 2000.

11.9% of hub 189, near the Chestnut Ridge Golf Course, was converted to low-density development. The majority of the vegetation left on this 31.2 acre developed site is mature forest, however less than 25% of the canopy remains intact. One hundred and fifty six acres of this hub's 185.5 acres is deciduous forest. Prior to development this hub's ecological rank was fairly low (eco-percent: 61.9).

Corridor 479 (1488.1 acres) links hub 160 to the hub-corridor network of this county. It lost 3.5% of its area to development, most of which was interior forest. At least one of the developments is now a medium density development. Less than 25% of the mature forest canopy has been retained on the developed site. This was not a high-ranking corridor prior to development, with ten breaks, two primary roads, five secondary roads, seven county roads and one railroad track. This corridor was broken in two locations. Alternate routes do exist, however between the breaks an area was isolated. These areas were previously broken by other land uses and therefore were not included in Table 8.

Hub 160 was an extremely high-ranking hub prior to development (eco-percent 1.3%). Of its 12, 965 acres, 6100 acres were interior forest. Unfortunately, development occurred at the entrance to corridor 510 (which leads to corridor 479). Three developed sites create an obstacle for this corridor network. There are alternate routes, however there are not any that are proximate. This pathway was obstructed by development prior to 1997 also, and therefore was not included in Table 8.

Within hub 161 is now found one of the 100 largest developed sites in Maryland. Forty-two of its acres were developed with low-density housing between 1997 and 2000. Fortunately, the developed area is at the edge of the hub. Less than 50% of the mature forest canopy was retained on the developed site. Hub 161 was relatively low-ranking (eco-percent 48.4%) before the recent development.

A portion of hub 150 (3000 acres), adjacent to Loch Raven Reservoir, has been impacted by recent development. Between 1997 and 2000 1.1% of the hub was lost, most of this development occurring in its periphery. Prior to the period of time examined, this hub's

ecological ranking was in the top five percent (eco-percent: 4.5) of the state.

A large slice of corridor 367's interior is now developed. This development placed in interior habitat may impede local animal and plant dispersal through the network. These developed sites abut previously human-impacted lands. Alternate pathways are present. Prior to development this corridor had only one break, one primary road and one secondary road. It connected to one of the highest-ranking hubs in the region (top tier 0.8).

A development in hub 188 abuts previously developed areas that block the pathway between the hub and corridor 440. There are alternate routes through hub 167. This break was not included in Table 8.

Hub 55 was also nearly broken. A narrow strip of developed area extends to the entrance of corridor 132. Only a thin opening for dispersal into the corridor exists. Alternates are present.

Corridor 138 was split by a developed site. Alternate routes are accessible for this broken path as well.

The connection between corridor 145, a top tier corridor, and hub 75 was broken. This connection was severed by previous land uses and therefore was not included in our final tally.

In all there were three complete or near breaks in the hub/corridor network in Baltimore County that were not previously impaired; alternates exist for all of these hubs/corridors.

Calvert County

In Calvert County, most of the development that occurred between 1997 and 2000 is located at the edges of hubs and corridors and does not seem to present any severe obstacles for animal and plant dispersal. Both interior and edge habitat were lost. Only one corridor, 1279, lost more than 10% of its area to development.

Linked corridors 1279,1267,1262 are all connected to hub 447. Developed areas are now found on the edge of, and in between corridors 1279 and 1267. The areas that have been developed are 7.9 and 1.6 acres, respectively. This is equal to or more than 10% of the total acreage of corridor 1279. Before development there were zero breaks in corridor 1279 (65.2 acres) and one city road passing through. This pathway was impaired prior to 1997 and was therefore not included in our analysis. Alternate routes are potentially accessible.

Two developed sites are now found in hub 447. The developed area may present an obstacle at the junction with corridor 1279, however it did not break the link.

Near the connection between hub 476 and corridor 1456, three developments now restrict the pathway in that region, however they do not completely break the connection. In corridor 476 there are now two other developments; one near corridor 1403 is potentially restrictive to dispersal.

A 63.5 acre development in hub 521 may impair the hub's connection with corridor 1619. This new development is in close proximity to a previously developed area, thus it may have further deteriorated the pathway.

A development at the junction of hub 525 with corridor 1619 may be obstructing dispersal through this pathway. The pathway between this hub and corridor was, however, previously severed by development. Alternate paths exist for this area.

No new connections were broken by sites that were developed between 1997 and 2000 in Calvert County.

Caroline County

Caroline County's hub and corridor network does not appear to have been severely threatened by development that occurred between 1997 and 2000. Both edge and interior habitat was affected, however none of this county's green infrastructure areas lost more than 10% of its area.

1.2% of corridor 1207 was developed over the course of this study. A developed site nearly broke the corridor, however corridor 1207 had two breaks before development and thus was not included in Table 8. Alternate paths exist that have not been developed.

A developed area in hub 375 now abuts previously developed areas near the entrance to corridor 1030. Previous land use severed this pathway. This corridor connects to one of the highest-ranking hubs in its physiographic region (top tier 1). It had one break, one primary and two secondary roads before 1997.

A portion of corridor 1092's interior habitat was developed. Before development it had no breaks and only one primary road. Corridor 1092 connects to one of the highest-ranking hubs in the state (top tier 1). This corridor connects hub 375 to hub 352. Neither is a particularly high ranking hub (eco-percent 27.2 and 72.4, respectively).

No hubs or corridors were split by development between 1997 and 2000 in Caroline County.

Carroll County

There is not much green infrastructure left in Carroll County. Between 1997and 2000 several small sites were developed throughout this county. None of the developed sites within this county impacts more than 10% of its respective corridor or hub's area, but the developed sites' placement may threaten the landscape's ecological function.

Corridor 63, a 353 acre corridor, lost 5.6 acres to development. The developed site is in the interior of a thin corridor and is adjacent to previously developed areas that did not sever the connection. It may no longer be sufficiently wide to function as a corridor. No alternate routes are present, since this corridor is the only connection for a series of hubs and corridors to the hub/corridor network.

Three developed sites (5.0 acres, 6.6 acres and 10.6 acres) are in close proximity in corridor 455. This corridor links hubs 160 and 199. Corridor 455 is not an essential link between these hubs

since the hubs themselves meet at another point. However, the three developed sites virtually break this corridor and make it impassable. This corridor was broken before these sites were developed. There are alternate routes between hubs 160 and 199.

An 8.1 acre developed site in corridor 528 (244.4 acres) abuts a previous break in the corridor. This corridor connects two hubs, 198 adjacent to Piney Run Lake and Park (670.5 acres) and 220 (402.2 acres). Alternate routes exist, however this route is most direct.

More than 10% of corridor 502 has been impacted by developed areas. This is a small corridor that is not linked to any hubs; it is peripheral to corridor 459 that links to hub 193.

In summary, one area in Carroll County was nearly severed by recent development, for which there are no alternate routes.

Cecil County

Most of the development in this county occurred in interior habitat, often in narrow regions in the hub/corridor network. In all cases alternate pathways exist, however they normally are distant and therefore may not be functional alternate routes.

Hub 28 (2207 acres prior to development) lost interior and edge habitat between 1997 and 2000. It was ranked in the top 10% of hubs in this region (eco-percent: 5.8%) prior to development. The damage may not be severe, since the developed sites are relatively small and do not appear to be an obstacle to movement within the hub.

Development occurred in a thin portion of corridor 41 adjacent to a previously developed area. This broke the corridor, and therefore may severely impede movement through this pathway. This corridor, together with other corridors links hubs 44 and 52. Alternate routes are available. An 11.1 acre developed site at the junction of corridor 60 and hub 16 nearly broke this link. Alternate, distant routes exist. This development abuts previously developed areas that did not sever the pathway. Corridor 60 connects to one of the state's highest-ranking hubs (top tier 1).

Both hubs 174 and 104 now have small, developments that cut into narrow areas and thus may impede dispersal through the hubs. These two impaired pathways are redundant pathways, thus alternate routes are present.

Developed sites are scattered through hubs 119 and 122, part of a hub system around the Elk Neck State Forest. They range in size from 0.2 acres to 83.8 acres. They are mostly found on hub edges, but a few also extend into the interior. Hub122 was ranked in the top ten percent of the hubs in this physiographic region.

Corridor 550 (112.7 acres) lost 15.4% of its area to development. This area previously had no roads or breaks prior to development.

Corridor 162 lost a large portion of land in a narrow region between previously developed areas. Alternate routes are accessible.

Several other corridors also experienced a small amount of development.

Altogether, three hub-corridor links were nearly or completely broken by recent development that were not previously impacted. For all three, alternate paths exist.

Charles County

Most of Charles County's developed areas are located at the edge of forest hubs and are small in size. Fortunately, where development occurred in corridors, alternate pathways are accessible.

A recently built low-density development abuts previous developments in hub 497 at its connection with corridor 1564. This connection was already severed by 1997. The developed area retains 75-100% cover and is primarily old regrowth. This is a very high-ranking hub, ranked within the top five percent of all hubs in its physiographic region (eco-percent 3.2). There are alternate routes present.

Another development site at the entrance to corridor 1591 from hub 497 abuts previously developed areas that broke the connection in this pathway. This site is a low-density site that retains at least half of its tree canopy. This corridor connects to one of the highest-ranking hubs in the region. It had one break, one secondary road, and one county road prior to development. Hub 497's periphery is also being developed.

Hub 508 lost large areas of interior forest. This hub is relatively highly ranked within its physiographic region (eco-percent 14.1%). Two developed sites within it now have low-density housing with approximately 25-50% of its young regrowth forest cover remaining.

A narrow pathway through hub 463 has now been developed and the passageway may be constricted. There are, however, alternate paths.

Corridor 1523 lost more than 10% of its area to development over the time period studied. It is connected to one of the highest-ranking hubs in the region.

Hub 493 experienced development at the entrance to corridor 1531. A 34.7 acre low-density development was built there that is adjacent to previous development. This connection was impaired before 1997. Alternate routes are present.

One pathway was broken by recent development in Charles County over the time period examined, however alternate routes are accessible for maintaining the network.

Dorchester County

Not much development took place in Dorchester County between 1997 and 2000.

A developed site in hub 511 effectively isolated a portion of the hub. 9.3% of the hub was developed. It was a very low ranking hub before 1997 (eco-percent: 81).

No hub/corridor pathways were split by development in the period examined.

Frederick County

Three corridors lost more than 10% of their area to development in Frederick County over the period examined. There was a significant amount of development in this county, impacting both interior and peripheral habitat, and in several cases presenting obstacles to movement within the corridor network.

Corridor 492 connects the Catoctin Mountains with the Potomac River. Two low-density residential sites, 185.3 and 34.9 acres respectively, may have broken the corridor. It has yet to be determined how functional low-density developments are for wildlife. These sites have retained at least 75% of their canopy cover. This corridor was also split at another site. For both, alternate, distant pathways are available. This corridor lost more than 10% to development. It was already severed by previous land use, and therefore these breaks were not included in Table 8.

Corridor 511 was split and retains 25% or less of its canopyafter development into medium-density residential site The forest canopy that remains is composed of older regrowth. Corridor 511's connection to corridor 489 was impacted, however this connection was already severed by previous development. Corridor 511 lost more than 10% of its area to development.

Corridor 576 was broken by a string of developed sites near its connection with corridor 586. These five developed areas form a narrow cut through the interior of the corridor, abutting protected areas and previously developed lands. More than 25% of this corridor's area was converted to developed land, but the connection may still be viable.

Corridor 612 was split by a development at the junction with hub 226. Hub 226 lost 75 of its 1834 acres. This connection was broken by land use prior to 1997. Alternate paths exist.

A small, developed area in corridor 429 abuts previous development that split the corridor. This corridor is linked to one of the highest ranked hubs in the region. Alternate paths are present.

Corridor 468 lost 25.1% of its area to development. One of two new developed sites is a medium density development with at most 25% forest cover remaining. Another 81.4 acre site has yet to be developed and retains its canopy. The main pathway is not broken. These two sites are in close proximity.

The development that occurred in Frederick County between 1997 and 2000 did not create any new breaks in the corridor and hub network. The breaks in this county's green infrastructure existed prior to 1997.

Garrett County

Many areas were developed in Garrett County between 1997 and 2000. Four hub/corridors lost more than 10% of their area to development. The majority of the newly developed areas are low-density housing, at the periphery of hubs and corridors.

Two low-density residential areas were built in hub 36 over the time period examined. Less than 75% of the mature forest canopy was retained in each. The developed areas broke hub 36's

connection with hub 47. Although there are alternate pathways that are potentially viable, almost all of them have had some degree of development.

Hub 7 had 879 acres of forest at the top of Meadow Mountain converted for low-density residential use. At least 50% of its young forest cover has been retained. This development did not completely split the hub. Alternate paths are potentially accessible. A small area within the hub is no longer connected to the hub-corridor network.

Hub 182 lost 28% of its total area to two developments (560 and 260 acres). These two developments abut one another and together split the hub. The smaller of the two sites is a low-density residential development with at most 75% of its canopy remaining. Alternate routes do exist.

Fourhundred thirty-nine acres of hub 235 have been developed in the middle of a ridge line and break a pathway within the hub. Alternate routes are present. A small portion of the hub is now isolated. This break is significant because it compensated for pathways within hub 235 that were lost to development prior to 1997. Alternate routes are potentially viable.

Corridor 354 lost 17% of its area to a development. The developed site completely obstructs the connection with corridors 349 and 350. It is a low-density residential site now that has retained at most 25% of its forest cover. This pathway was severed prior to 1997. There are alternate distant routes, however the pathways in this region are almost all impacted by some degree of development.

Hub 56 is beginning to see development in state forest in-holdings. This hub is mostly composed of Savage River State Forest and is one of the highest-ranking hubs in Maryland. The developed areas are mainly low-density housing in interior and edge habitat and retain at least 50% canopy cover. New development is also occurring along the Potomac River.

Several low-density residential developments have been built in hub 58 between 1997 and 2000. A cluster of these sites blocks minor internal connections within the hub. They are mostly low-density residential developments that differ in the amount of forest cover that has been retained. One of these breaks retains at least 75% of its canopy, the other retains at least 50% of its canopy. Other developed sites nearly block hub 58's connections with corridors 318 and 321. These connections were broken prior to 1997. One of the largest of these developments is a medium-density residential site that retains at least 75% of its forest cover. There are alternate pathways for all these breaks. The majority of these new developments are extensions of older developments.

Corridor 256 was split by several small developments. One of these sites was planned to be developed but had not been by September 2002. If this forest area remains intact the corridor may still be functional. This corridor had been severed by development prior to 1997. Alternate routes are present, although some have been impacted by recent development as well.

Corridor 359 and hub 181 both lost more than 10% of their area to developed sites.

In total, three hub/corridors were split by developed sites in Garrett County between 1997 and 2000. For all there are alternate pathways present. Two of the developments that severed the green infrastructure network in this county are now low-density residential developments.

Harford County

Not one of Harford County's hubs or corridors lost more than 10% of its area to development, however there are areas where the arrangement and location of the developed sites may threaten hub/corridors' function. In this county almost all development occurred within corridors and not hubs.

Corridor 293 lost only 4.4% of its area, however three developed sites in close proximity to one another create a narrow passage, which may restrict dispersal. This corridor was already severed by previous land use prior to 1997. Alternate pathways are present, but distant. Prior to development, this was not a high-ranking corridor, with twelve breaks, and one primary, three secondary and two county roads. This corridor is linked to one of the top ranking hubs in its physiographic region (top tier 1). The developed sites are close to hub 112.

A number of developed sites may have compromised the function of corridor 383. Corridor 383 lost 4.7% of its area to four staggered developed sites. Prior to development 383 was not a high-ranking corridor. It connected to one of the highest ranked hubs in the state (top-tier 1). This corridor was split by developed sites prior to 1997.

Corridor 411 lost 5.2 % of its area to development. One developed site nearly split the corridor. Alternate routes are viable.

A small developed site in corridor 438 abuts a previously developed area. The corridor was split prior to 1997.

Other development in this county was mostly small scale, with development occurring at the periphery of corridors and hubs.

In total, one pathway was split by development between 1997 and 2000 in Harford County. Alternate paths exist for this impaired route. There was no field verification of the type of development that occurred.

Howard County

Not much development occurred in Howard County forests over the time period studied. As in other counties, the cumulative effects of several, small developments together may have impaired the function of a few of Howard County's hub/corridors.

Development has potentially impacted the function of corridors 726, 732 and 734. Corridor 732 now has two developed areas and lost 14% of its interior area. Corridor 726, adjacent to 732, was developed in four small areas. Although no development occurred in corridor 734, this corridor links to corridor 726 and 732 close to the cluster of developed sites. Development occurs where these corridors intersect, and the resulting bottleneck might create a pathway that is too narrow for dispersal. All potential alternate paths in this region have been impaired by prior

development and do not appear to be functional connections within the network. The break that resulted from development in corridors 726 and 732 was not included into our final analysis since the connection was first severed prior to 1997.

A site developed in the time period of this study broke corridor 711. This corridor connects hub 253 and 284. It had seven breaks, crosses nine roads and retained 64% natural cover prior to 1997, therefore this break was not included in our analysis. Alternate routes are distant, and questionable since they have all been developed to some degree the time period examined.

Corridor 661, previously had no breaks and connected to one of the highest ranked hubs in the region. It now has a 45.4 acre medium density development that stretches through its interior. At least 50% of the developed site's mature forest canopy has been retained.

No hubs/corridors were split by developed sites between 1997 and 2000 in Howard County.

Kent County

The amount of development that occurred in Kent County between 1997 and 2000 was minor. However, the placement of the developed areas within the green infrastructure appears to be more threatening than the size and number of developed sites, since often they are located in narrow areas.

Although only 1.7% of corridor 611's area was developed between 1997 and 2000, it nearly broke the corridor. This corridor links hub 231 with protected areas. No alternate routes are present.

Also, a newly developed area spans the link between corridors 630 and 593. The connection was not completely severed however, and alternate routes appear to be available.

Corridor 807, totaling 537 acres, lost 7.4 interior acres between 1997 and 2000. The new development may restrict passage through the corridor, however it does not sever the pathway.

Summing up, one corridor was split by development in Kent County between 1997 and 2000. There are no alternate routes that can compensate for this lost pathway.

Montgomery County

Many new, small developments located close to each other, or near previously developed areas have obstructed the hub/corridor network in Montgomery County.

Corridor 783 has lost 30% of its area and was split by a development. The neighboring corridor 796 was also partially broken, and its connection to 783 was completely obstructed. Corridor 796's connection to corridor 804 has also been blocked by a developed site. Therefore, this developed area broke two connections within this region. Alternate pathways are present.

Hub 331, Big Pines Serpentine Barrens, lost 20% of its area. The developed site is a low – density development, with less than 25% of its mature forest retained. Its connection to corridor

904 was completely broken, however this hub was isolated by development in the region prior to 1997.

Corridor 827 is still at least 75% forested, however a golf course and low density residential area extend through 827 and a portion of hub 312. A portion of this area is currently slated for development but has not been developed yet. The corridor/hub link will be completely split by this developed site and adjacent development. Since this pathway was broken prior to 1997 it has not been included in Table 8.

Hub 308, adjoining hub 312 was also broken by a developed site. This pathway is surrounded by dense development, and was therefore not a major link in the network. It has not been included in this study's final tally of hub/corridor breaks/county.

The connection between corridors 844 and 845 has been blocked by a 66 acre medium to high-density development. This obstruction affects a small portion of 844's area that has been isolated. Prior to 1997 it had been isolated from the hub/corridor network and therefore has not been included in our final analysis.

Corridor 908's connection to hub 249 may potentially be broken by a 34-acre planned development. Its mature forest cover has, as of yet, been retained. Corridor 908 had been isolated prior to 1997, therefore this break has not been added to our final tally of breaks/county.

Corridor 675 was split by a 5.7 acre development. Alternate routes are present, however they may be impacted to some degree by previous development.

Corridor 777 has been nearly broken by a site, developed between 1997 and 2000, that abuts previously developed areas. This pathway was severed prior to 1997. There is therefore an interruption in the linkage between Patuxent River and Rock Creek/ North Branch.

Corridors 781, 791 and 765, and hub 292 were all impacted by 2 developed sites. One of the sites, located in corridor 791 completely obstructed the connection with corridor 765. Alternate routes are nearby and most likely accessible.

In all, between 1997 and 2000 four sites have been developed that have split or isolated regions of Montgomery County's green infrastructure. All have alternate routes. This does not fully represent the degree of development that took place in this region between 1997 and 2000 since previous development had broken many of the corridors and hubs in Montgomery County.

Prince George's County

Three corridors in this county had or are planned to have more than 10% of their area altered by development. In general, the southern region of the county has been relatively unaffected by development. The interior of the county, however, has been affected by small, scattered sites that broke several connections within PG County's green infrastructure. For several there are no alternate pathways.

Hub 326 was developed in an area that abuts previous development. Together, these developed sites break the pathway near a connection with corridor 933. This route was a short, dead end pathway prior to 1997. For this reason it was not included in Table 8.

A developed site broke the junction between corridor 1004 and hub 347. Corridor 1004 in turn connects with corridor 1011. This pathway connects hub 347 with hub 372. Corridor 1011 was broken in two locations. Although new breaks have occurred since 1997, these connections were broken prior to 1997 and therefore have not been included in our final tally of breaks/county. This was not a significant pathway through the network of hubs and corridors since it had been broken in the past.

Corridor 983 was broken near its connection with hub 323. This connection was initially split prior to 1997. The developed site is an extension of previous development.

Within hub 323, a new medium density development has been built that covers more than 10% of the hub's area. Before development, this hub's ecological rank was within the top 10% of the state (eco-percent: 8.6). Less than 25% of the forest canopy remains in the developed portion and is composed of young regrowth. This development occurred at the periphery of the hub.

Corridor 1131 lost 15.1% of its area to development. It links hubs 395 and 403. The developed areas broken the corridor. Corridor 1131 was split prior to 1997. Alternate pathways exist.

Corridor 1120 is slated to lose13.7% of its interior habitat, which was planned to be developed between 1997-2000, but had not been as of Autumn 2002. There was one break in this corridor prior to 1997. Corridor 1120 links hub 395 to hub 397. Alternate routes are distant. The closest route is through corridor 1127, which lost 5.5% of its area to development between 1997 and 2000 and was severed prior to 1997. Another potential route, through corridor 1151, was broken by a small, developed area between 1997 and 2000, but it had also been broken prior to 1997.

Hub 387 also lost a large portion of its interior to a 47-acre development. Buildings are on the site, and less than 25% of the canopy has been retained. This is very close to Great America Theme Park and Belt Woods Natural Environment Area. There are several other developed sites in this hub that broke the pathway prior to 1997. All of the habitat that was converted was interior habitat. Alternate routes are accessible.

A string of small developments is located in hub 419 that obstruct its connection with corridor 1175. There are two other developments within corridor 1175 that may make dispersal through this area difficult. These pathways were severed prior to 1997. Alternate routes are present.

A narrow area in hub 426 was developed adjacent to previous development, further constricting the pathway, nearly breaking the integrity of the hub. The pathway was not completely lost, however, and alternate routes are potentially viable.

Hub 385 lost 2.5% of its area to development, isolating a portion of the hub. This hub is adjacent to Enterprise Golf Course.

All of the green infrastructure pathways that were severed by sites that were developed between 1997 and 2000 had already been impacted by development.

Queen Anne's County

Queen Anne's County lost both edge and interior habitat to development. For almost all of the areas that have been developed, there are alternate accessible links For maintaining the network.

Twelve sites in corridor 928 were developed between 1997 and 2000. This corridor lost 12.1% of its area. Thirty-nine of the hub's 318.7 acres were lost. The majority of this development replaced interior habitat. One developed site (8.7 acres,) nearly broke the corridor. The corridor was initially broken prior to 1997. Corridor 928 is linked to one of the highest ranking hubs in its region (top tier 1). The corridor had no breaks, 1 secondary road and two county roads prior to development.

Corridor 959 was almost completely broken by a developed site. Alternate routes are available.

13.6 acres of interior habitat have been developed in corridor 909 and may severely restrict passage through the corridor.

Corridor 911, a 103-acre corridor, lost 5.6 acres of interior forest to development over the time period examined.

One corridor was split by development between 1997 and 2000. Alternate paths are present to compensate for this broken pathway and maintain network function.

Somerset County

Not much development occurred in Somerset County over the time period studied in this report. The connection between corridors 1917 and 1926 was impaired due to two adjacent developed sites, together spanning 6.6 acres. This connection was already severed by previous land uses. Alternate routes are present.

St. Mary's County

Several sites have been developed in this county, breaking links between hubs and corridors and cutting into interior forest.

Hub 614 had the largest area developed in St. Mary's County over the time period examined. It lost 14.7% (124.7 acres) of its area to low-density development. Field examinations showed that canopy cover was broken across the hub. This hub is on path between hubs 606, 613 and 618, all of which have experienced development between 1997 and 2000. Alternate routes may compensate for this break in the hub and corridor network.

Forty-nine acres of hub 606 have been converted to medium density development. The developed area extends into the forest interior of this hub, however the pathway through the hub may still be functional. Less than 50% of the developed site's mature forest canopy remains intact.

Hub 545's connection to corridor 1714 has been impaired by a 27.8 acre developed site. Alternate routes are available. This pathway had been impaired by other land use prior to 1997.

Hub 548, a 6967 acre hub, lost both interior and edge habitat between 1997 and 2000. A 139.8 acre development cut deep into the interior of this hub. It is now a medium intensity residential development which retains 25-50% of its young forest canopy. Another smaller development, 13.6 acres, almost completely blocked the connection between hub 548 and corridor 1665. This connection was broken prior to 1997. Alternate paths may be present.

Hub 613, a coastal plain habitat, lost 9.1% of its interior area to low-density development. The developed area stretches into the interior of the hub. Post-development, the forest retains less than 75% of its mature forest canopy.

Hub 588, 3248.5 acres, lost 4.2% of its area to five development sites. One of these developments is a long, narrow, low-density area that cuts into the heart of the hub. Currently, less than 75% of the forest canopy remains and is composed of young regrowth. The other sites are all scattered in the periphery of the hub. Two of these sites (one medium density, one low density) retain approximately 25-50% of their forest cover.

Another relatively small (9.7 acre) developed site, nearly broke hub 508 at a narrow point in the hub. This region in the hub was already broken by 1997. Hub 508 was a relatively high-ranking hub before development took place (eco-percent: 14.1). Alternate paths are distant, but present.

Summing up, one developed area in St. Mary's County broke a hub/corridor pathway between 1997 and 2000. Alternates routes in the network are available.

Talbot County

Very little development occurred in Talbot County over the timeframe of this project. However, the sites that were developed converted interior forest, or were placed at the junction of hubs and corridors.

Interior forest within hub 407, near Miles River and Gully Cove, was converted to a 57.7 acre developed site. This coastal plain hub was relatively high ranking (eco-percent 12.5) previously.

A developed site at the junction of hub 406, corridor 1132 and corridor 1136 now obstructs this connection. Hub 406, a 443 acre hub, lost 4.6% of its area. Hub 406's connection with corridor 1132 was completely blocked. Alternate routes are potentially viable and proximate.

Within the overall network, one hub/corridor pathway was split by development in this county between 1997 and 2000.

Washington County

Not many natural areas have been retained in Washington County. There are many scattered developed sites throughout its remaining green infrastructure. These areas are particularly dense around the South Mountain Natural Environment Area, the Fort Ritchie Military Reservation,

Hagerstown Watershed and Catoctin National Park. The entire central region of the county surrounding Hagerstown has lost its forests.

Four developed areas in corridor 392 and one developed site in hub 116 have nearly broken corridor 392, adjacent to the Chesapeake Ohio Canal along the Potomac. This is a small corridor nestled within hub 116. Corridor 392 lost 29.2% of its area to development. Prior to 1997 this corridor was almost completely developed. Several other sites have converted interior and peripheral habitat to developed areas in the hub and corridor network that runs along the Potomac River in this County.

Hub 26, a 122,091 acre hub, was split at one of its narrowest points by two small, developed areas (0.2 and 6.2 acres). There are alternate routes for this split pathway in the overall network.

Hub 10 (3568.8 acres) was nearly split by two developed areas, 12.4 acres each. The developed area is located in a narrow region of the hub. Other paths that could compensate for losing this link in the network are distant, and narrow.

A developed site in hub 70 isolated a small portion of the hub.

Hub 82, adjacent to the Indian Springs Wildlife Management area, was broken at one point by a 26.5 acre development site, at its entrance to hub 6. This connection was initially broken prior to 1997. Alternate paths do exist. Other developed sites are now found around this wildlife management area, however most are found at habitat edges and do not seem to severely impair the forest network in this region.

There are now several developed sites in the periphery of hub 6, a large (26,354.5 acres) area in north-central Washington County. One of these developments is a 123.6 acre site. Another developed area in this hub nearly blocks its connection to corridor 95. Alternate routes are present.

Hub 96 is a thin hub that lines the Potomac River. One hundred and four acres were developed within a narrow area of the hub abutting a protected area. The protected area may compensate for habitat losses within the hub, depending on the condition of the protected area.

A developed area cuts into corridor 303, nearly breaking it. Corridor 303 runs through the southeast portion of Washington County. It had 21 breaks, 11 county roads and 4 secondary roads prior to the more recent development. Three developed areas near the connection between corridors 303, 454, and 448 may also constrict passage between the corridors. This pathway to hub 180 was impaired prior to 1997. There are alternate, distant routes for this pathway.

Hub 180 (11,920.8 acres) lost 2.2% of its area to development. Two areas within this hub were completely split by developments. One of these areas was initially split prior to 1997. One of the developed sites (154.9 acres) was field-verified as a low-density development which retains 75-100% of its mature forest canopy cover. Alternate routes are potentially available, however this is dependent on the status of this region's protected areas. The closest alternate route would be through corridors 303, 454 and 448, which have been impaired by recent development also.

There are several developed sites near the Indian Springs Wildlife Management area and Fort Frederick State Park, close to the Potomac. Several peripheral areas have been developed in hub 29 (23015 acres). The hub was split by one of these developments (100 acres), located in a narrow portion of the hub that leads into Frederick County. There are alternate paths for animal and plant dispersal.

In summary, four hubs/corridors were broken by development between 1997 and 2000 in Washington County. For all of these breaks there are potential alternate routes for plant and animal dispersal. One of these breaks was field-verified and is now a low-density residential site with approximately 75-100% of its canopy cover retained.

Wicomico County

Very little development occurred in this region. Three corridors in this county lost more than 10% of their area to development between 1997 and 2000. Alternate links exist where connections in the green infrastructure have been severed.

Corridor 1747 lost 18.1% of its interior habitat to development. This corridor is linked to one of the highest-ranking hubs in Maryland (top tier 1, best hub 2). The developed sites abut developed areas that broke the corridor prior to 1997. Alternate routes are nearby, including hub 575.

Corridor 1740 lost 20.6% of its area to development at two sites. One is a long, narrow strip through its interior and the other is located at the boundary of hub 575. This corridor is also linked to one of the highest-ranking hubs in this region (top tier 1, best hub 2). It had zero breaks, one secondary road, and one county road prior to development. This connection is now nearly severed, although alternate routes exist in this region.

Corridor 1658 lost 14.3% of its area over the time period examined. This corridor had zero breaks, roads or railroad tracks before recent development. The newly developed site spans the link between corridor 1658 and corridor 1674, breaking the pathway. Corridors 1568 and 1674 connect hub 539 and corridor 1671. This pathway had been severed prior to 1997, and therefore this break has not been included in Table 8. Corridor 1658 lost 7.1% of its area and was split by the developed site. Alternate routes are present.

One corridor was broken by recent development in Wicomico County. There are potential alternate routes for wildlife dispersal, compensating for this lost pathway through the hub/corridor network.

Worcester County

Development was fairly minor in this county, which still retains a large amount of green infrastructure. The few sites that were developed are small, and mostly found at the edge of the hub and corridor network.

One corridor, corridor 2017, lost 18.2% of its area between 1997 and 2000. This development split the pathway leading to hub 642, one of the highest-ranking hubs in the region. Hub 642 is a relatively intact, high-ranking hub (eco-percent 2). Alternative routes to this hub were present.

In this county, one hub/corridor path was broken by a developed site between 1997 and 2000. Alternate routes were available.

Table 8
Number of breaks within the hub/corridor network in Maryland by county.

County	Number of breaks	Number of breaks with alternate routes		Number of breaks field verified	Breaks that are low-density develop-ments	Breaks that are medium-density develop-ments	Breaks that are high-density develop-ments	Breaks that are planned develop-ments
Allegany	0	0		0				
Anne Arundel	2	0		2 (1 commercially developed)				1
Baltimore	3	3		0				
Calvert	0	0		0				
Caroline	0	0		0				
Carroll	1	0		0				
Cecil	3	3		0				
Charles	1	1		0				
Dorchester	0	0		0				
Frederick	0	0		0				
Garrett	3	3		2	2			
Harford	1	1		0				
Howard	0	0		0				
Kent	1	0		0				
Montgomery	4	4		0				
Prince George's	0	0		0				
Queen Anne	1	1		0				
Somerset	0	0		0				
St. Mary's	1	1		1		1		
Talbot	1	1		0				
Washington	4	4		1	1			
Wicomico	1	1		0				
Worcester	1	1		0				
TOTAL	28	24		6	3	1	0	1

Evaluation of development risk model

63% of forest converted to development between 1997 and 2000 fell within hubs or corridors in the top 50% of modeled development risk. Looking at a finer scale, the mean cell risk of all 1997 forest in the green infrastructure was 27.4 (out of 100, where 100 is the highest risk of development in the state, and 0 is the lowest risk). Disregarding protected land, the mean cell risk of all 1997 forest in the green infrastructure was 37.0 (std = 27.0). The mean cell risk of forest converted to development 1997-2000 in the green infrastructure was 56.3 (std = 25.4). 9592 ac (64%) had a risk 50-100, and 5479 ac (36%) had a risk 0-49. A better cell risk threshold was 45: 75% had risk 45-100, 25% had risk 0-44. 90% of developed cells had a risk >25.

DISCUSSION

Surprisingly, Garrett County suffered by far the greatest loss (over 6,000 ac) of green infrastructure forest between 1997 and 2000. Washington County was second. Western Maryland lost the most overall forest to development of any region of Maryland, although it had the most to begin with. Three of the four regions (Western, Southern, and Central) lost about 2% of their overall forest, whereas the Eastern region lost only 0.3%. Western Maryland also lost by far the most green infrastructure, both in absolute and percentage terms. In fact, Western Maryland lost more green infrastructure than the rest of the state combined. Most of its forest loss was in formerly large, contiguous blocks; whereas much (71%) of the forest lost elsewhere in the state was in small or isolated woodlots, and outside the green infrastructure. This reflects the fragmented state of most of Maryland's forests. Western Maryland (especially Garrett County), on the other hand, had more contiguous, more ecologically and economically valuable forest, but is now undergoing the same sort of exurban development and habitat fragmentation that has plagued the central and southern counties.

More attention should be paid to the development of Garrett and Washington counties: why it is occurring, what the potential impacts might be, and how to address it. Most (92%) of the development in Garrett county was low-density residential; the remainder was medium-density residential. Perhaps the scenic character of this area attracts owners of second homes or retirement homes. Bockstael (1996) found that the amount of preserved open space surrounding a parcel increased its value. Unfortunately, as a scenic area is developed, it loses much of its scenic character, and people look for other scenic areas to live in. A similar circumstance results from individuals or families wanting more space and fewer neighbors; again, a self-defeating process.

The Eastern Shore, where much of recent land protection effort has been focused, suffered by far the fewest losses of forest and green infrastructure during the study period. The Eastern Shore is largely still agricultural, though. Most forests on the eastern shore are either wetlands, protected areas, or active pine plantations. There are areas of active development, such as along Route 50 near Ocean City, on Kent Island, and in the Cambridge and Salisbury areas.

Using the Maryland Department of Planning's (MDP) Growth Simulation Model, 93,000 acres of green infrastructure forest were predicted to be lost between 1997 and 2020 (see *An estimate of GI loss by 2020* for details). However, 15,468 acres were lost in just a recent 3-year period (1997-2000). If this trend is extrapolated to 2020, an additional 103,000 acres of GI forest would be lost, which is somewhat greater (by 28%) than MDP's scenario. More significantly, the location of these forest losses is different. MDP projected low forest loss (1-6%) in Garrett County between 1997 and 2020, yet this county had by far the greatest total forest losses in absolute terms between 1997 and 2000, and among the highest in percentage terms.

Field surveys were conducted to verify the accuracy of the GIS data. Nearly 90% of the sites (and 95% of the area) that were deemed developed using GIS data were in fact built upon. We can infer, therefore, that the GIS data are relatively accurate.

Maryland's GreenPrint program protected 10,197 acres in 2001. Of these, 9906 acres were in the GI. If funding for GreenPrint between 2002 and 2020 matched that for 2001 (after adjusting for rising real estate prices), the GreenPrint program might protect 198,000 acres (rounded to nearest 1000 ac). This would exceed GI loss (counting from 2000) by 95,000 ac. The amount of GI would still decline (unless all development proposals in the GI are preempted by GreenPrint purchase of the land, or other action is taken). However, the GreenPrint program would protect more area than would be lost. Of course, if GreenPrint funding is discontinued, this will not be the case.

However, area loss tells only part of the story. Habitat fragmentation is as big a problem in urbanizing areas as is habitat loss. The scattered pattern of modern development not only consumes an excessive amount of land, it fragments the landscape. Sorrell (1997) states, "the end result of fragmentation is often a patchwork of small, isolated islands of habitat in a sea of developed land". Numerous studies have shown the negative ecological effects of forest fragmentation in the landscape. Some generalist or ecotone species, like white-tailed deer and raccoons, can benefit from fragmentation. But according to Sorrell (1997), habitat fragmentation is perhaps the greatest worldwide threat to forest wildlife, and the primary cause of species extinction. Yahner (1988), Hansen and Urban (1992), Donovan et al (1995), and Robinson et al (1995) showed that fragmentation and increased edge have reduced the distribution and abundance of forest birds and other wildlife species throughout North America. As forest areas are divided and isolated by roads and development, interior habitat decreases, human disturbance increases, opportunistic edge species replace interior species, and populations of many animals become too small to persist.

Therefore, it is important to consider the location of development when assessing the impact of the converted forest on the landscape. Our results show that most of the surveyed areas are now low-density residential areas that have retained between 50-100% of their forest canopy. Although the amount of residual forest appears to be high on these sites, most of it abuts low-density developed areas. The amount of edge habitat is not accounted for by these assessments.

Many hubs and corridors appear to be severely compromised by recent development. The hub-corridor network was interrupted in several areas. There were 28 new pathways (hubs/corridors) broken by recent development that were not broken prior to 1997. Of the 28 breaks, 24 had potential alternative routes for dispersal. Garrett, Baltimore, Montgomery, Cecil and Washington counties had the most hubs/corridors broken by developed areas in Maryland between 1997 and 2000. Garrett, Cecil and Baltimore Counties had three connections broken by recent development, Montgomery and Washington Counties had four connections broken. For all these new breaks in the hub/corridor network alternate pathways exist. In some cases they may be distant. Of the six broken hub/corridor connections that were field verified, three are now low-density residential developments (3 of 6). These three sites varied greatly in terms of the amount of forest cover that was retained. This broad inspection of development impacts to Maryland’s green infrastructure can help determine where to focus further attention for protecting the GI network in Maryland. Field analysis should be conducted to determine whether the function of hubs or corridors impacted by development has been degraded.

In this study, we did not include the number of corridor/hub pathways in Maryland's green infrastructure that were broken prior to 1997. Counties in which the majority of natural areas were lost to development prior to 1997 naturally had fewer hub/corridor breaks caused by development between 1997 and 2000 than counties that retained more green areas by 1997. Therefore, this was not reflected in our analysis. Prince George's County in fact lost 3,415 acres between 1997 and 2000, the third largest amount of land converted in the state over that period of time but had no new hub/corridor breaks between 1997 and 2000.

It is apparent from this survey that redundancy within the network is useful if the web of hubs and corridors in Maryland is to remain functional. Alternate pathways through the hub/corridor network compensate for the obstacles posed by development. Judging from the data, broken pathways through Maryland's green infrastructure are usually compensated for by alternate routes that have not been impacted by development. The ecological function of these routes may be dependent on the species in consideration. The data in this analysis are skewed to favor presence of alternate paths because they did not include small portions of hubs/corridors that were isolated. We only considered breaks that cut a path through the network of hubs and corridors. For that reason, there almost always is a corridor or hub that can serve as an alternate; however, it may be distant. This variable needs to be assessed in further surveys.

Corridors may be especially important in regions where hubs are fragmented and may not provide adequate habitat for dispersing species. While corridors have been shown to be important for promoting animal and plant dispersal between otherwise isolated regions, they also provide habitat for species living within them. In counties such as Frederick, Howard, Carroll and Montgomery, for example, where very few intact natural areas are left, corridors are not only functioning as throughways but may be compensating for area losses by providing supplementary habitat (Bennett, 1998; Weber, 2003).

Development within a corridor, thereby narrowing the corridor's width, may significantly impact its ability to facilitate animal and plant dispersal. The quality of a corridor (based on its width, composition, the degree to which it is intact or severed, etc.) affects the survival of dispersing species, and metapopulation sizes in the patches the corridors connect (Anderson and Danielson, 1997). Narrow corridors may be impaired by edge effects, including increased predation, parasitism, exotic species, human disturbance such as noise, etc. (Forman and Godron, 1986; Harris, 1989; Lidicker, 1999). The importance of corridor quality has been shown repeatedly. For example, in wide corridors the migration rates of perennial grass seeds are similar to those in continuous habitats. Seed losses through wide corridors are low, as compared to losses while dispersing through narrow corridors (Van Dorp et al., 1997). Therefore, development within narrow regions of Maryland's corridors may severely impair dispersal though the green infrastructure network.

Development appears to have occurred in Maryland without much attention to ecological functions and requirements of the green infrastructure. On inspection of developments built between 1997 and 2000, many small developed sites are now found at junctions between hubs and corridors, or in bottlenecks, thus creating obstacles and likely affecting ecological functions. Therefore, the impact of these developments is not reflective of their size, but their location. The same developments, if positioned along GI periphery, or adjacent to previous developments, would be much less detrimental to Maryland's remaining hubs and corridors. The Green

Infrastructure Assessment could be useful in informing decisions on permitting and land use planning. This assessment can help Maryland be proactive about guiding future development away from interior forest or corridor entrances.

According to MDP's Growth Simulation Model, 243,000 ac of GI (224,000 ac of which is currently unprotected) is projected to be significantly impacted by development in the next 18 years (see *An estimate of GI loss by 2020* for details). Given that development is proceeding at a rate greater than that forecast by the model, and that more of this recent development is occurring in green infrastructure-rich western Maryland than was forecast, a large fraction of Maryland's green infrastructure may be seriously degraded by 2020.

Looking purely at numbers, the GreenPrint program seems to have great potential to protect Maryland's green infrastructure, if continued. However, it is important to spend this money strategically, and tie in protection efforts by other entities, as well as regulating development in these areas. GreenPrint can only partially meet the demand. Strong zoning plans and enforcement (unlike those found in many Maryland counties) could steer development away from the GI and other important or sensitive ecological areas. Other protection mechanisms include easements both donated and purchased by the Maryland Environmental Trust (MET), fee-simple purchase by Program Open Space (POS) state side, POS local side, land trusts, forest land donations by power companies to offset greenhouse gas emissions, etc.

The development risk model was a useful, but not infallible, predictor. Decisions to develop a parcel depend on the intentions of the landowner and developers, which cannot always be predicted by models. However, the development risk model performed better than random chance, and by using suitable thresholds, can help focus protection efforts. For example, hubs and corridors with their unprotected portion averaging above 45 on the development risk are 3 times more likely to be developed than hubs and corridors averaging below 45, if 1997-2000 trends continue. A threshold of >25can be used with even more confidence (90%). Landowner intentions, local knowledge, and field signs of development pressure should be taken into account when considering protection of individual parcels. Development risk should be combined with ecological data (both GIS and field), which are generally more reliable.

A more comprehensive study might compare all land use or land cover change over time. For example, agricultural land has also been converted to housing, but this fell outside the scope of this paper. We are currently following up the forest loss study by constructing an improved development risk model, based on logistic regression of development constraints and incentives against a random sample of green infrastructure forest sites that were either developed or not. This model will be validated with an independent sample of converted or unconverted GI forest. We also plan to study the effects of low-density development on bird and plant communities, and possibly other ecological health indicators. Numerous studies have shown the negative impacts of forest fragmentation on natural communities, as well as the effects of roads, noise, pet predation, and the introduction of exotic species. However, few, if any, studies have explicitly examined the impact of low density development where most of the canopy cover was maintained. We hope that these studies, as well as those presented in this report, can help guide managers and planners in the decision-making process.

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